Introduction to Neuroscience: Behavioral Neuroscience

Lecture 1: Introduction to Animal Behavior

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* Presentation Materials for Personal Use ONLY
Introduction

- Humans have always studied animal behavior
  - Knowledge of animal behavior = human survival
  - For example, understanding behavior of animals hunted for food

* Cave animal paintings (ca. 30,000-10,000 BC)
What is behavior?

- Series of coordinated muscle contractions
- Organized into motor patterns or units
Are there common principles (laws) in animal behaviors?

Dominant- Submission (aggressive) behaviors
Does animal behavior and human behavior use the same laws?
Aggressive behavioral posture in animals and human
Courtship behavior in animals and human
Introduction

- Ethology - Study of behavior (in nature) & its relationship to its evolutionary origins
  - The study of how animals behave, especially in their native habitat

- 3 important ethologists founders:
  - Karl von Frisch - Honeybee communication
  - Niko Tinbergen - Fixed action pattern
  - Konrad Lorenz - Imprinting
Founders of animal behavior study in the natural habitats (Ethologist)

Niko Tinbergen (1907-1988)
Konrad Lorenz (1903-1989)
Karl von Frisch (1886-1982)

The Nobel Prize in Physiology or Medicine 1973
"for their discoveries concerning organization and elicitation of individual and social behavior patterns"
Causes of Behavior

Animals behave in ways that maximize their fitness

Fitness = the ability to survive and reproduce
Behavior adapted to the animal’s niche

- Animal’s behavior evolved through the animal’s interaction with its environment

- Animals adapt to environmental conditions they encounter in their surroundings

- **Adaptation** = any characteristic that enhances an organisms survival or reproductive success

- **Environment** = the living (biotic) and non-living (abiotic) surroundings of an organism
Darwin’s theory of natural selection of behavior (evolution of behavior)

1. Variations also exist in behavioral traits

2. Some of these behavioral variations are heritable

3. Certain behavioral variations make individuals better adapted to their environment

4. These individuals have the chance to survive longer and leave more offspring than those with less successful behavioral traits
Darwin realized that some (behavioral) traits directly relate to mate acquisition and mate choice.

He termed this evolutionary process “sexual selection”.

**Sexual Selection** “...depends on the success of certain individuals over others of the same sex, in relation to propagation of the species...”

Charles Darwin 1871
Example: Sexual selection of behavior
The Lyrebird courtship behavior
Sensory adaptation to the unique environment *(Umwelt)*
The organism's model of the world: the perceived things in the world, the signals emitted by both the subject and things, and the actions that are performed by each species.

Von Uexküll (1921) intended his idea of the *umwelt* to apply principally to physical stimuli (i.e. water, food, shelter, potential threats, reference for navigation).

Lorenz (1935) extended this concept by recognizing that animals also have a social *umwelt* since signals from other individuals can have important influences on their behavior.

These signals are perceived by set of sensory channels that are adapted to the unique species survival needs and its niche (biotic and abiotic components).
Example 1: animal behavior adaptation to its environment

The blind mole rat social communication
Rodentia
Mole-Rat

Blind mole rat
Naked mole rat

Insectivora
Mole

Star nose mole
European mole
Mole rat - side view
Mole rat - Front view
Two patterns of mole rat mounds in Israel
Female mole rat (1390)
4–5/3/91

Total tunnel length = 66.0 m.

Pause site
Nest
Mound

5m.

Courtesy: Dr. I. Zuri
Burrows excavations is both costly and difficult

- High energy cost: up to 3400 times more than moving on surface
- High CO$_2$ pressure (~13.5%) and low O$_2$ pressure (~5.5%)
- High risk of body overheating (unventilated niche)
- High risk of losing water and consequent dehydration (food is the only water source)
Mole rat exposed to unique environmental conditions
Sensory adaption to the underground niche
How does the blind mole rat communicate with each other (find their mate/ avoid aggressive males)?
Airborne Sound is Quickly Attenuated in Soil

![Graph showing total attenuation (L_{A_{eq}}) in dB vs distance from source in meters. The graph includes lines for minimum, mean, and maximum values.](image-url)
Behavioral observations:

Mole rats produce head drumming
Mole rats often press their lower jaw to the tunnel side

Hypothesis:
Mole rats communicate using soil-borne vibrations
Lab experiments
Middle latency response (MLR)
Middle latency response (MLR)  
MLR is thought to represent the synchronous firing of neurones in the primary auditory cortex to an acoustic stimulus.
Middle latency response (MLR)

Jaw is barely touching the tube

Jaw is laying on the tube

Jaw is firmly pressed against the tube surface
Vibration frequency

Rate: 0.5/s

Rate: 7/s

Middle latency response (MLR)
Vibration signals detection via bone conduction
Video - Communication in blind mole rat - video
Example 2: animal behavior adaptation to its environment

The Meerkat social communication
The Meerkat social communication-video
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Scientific Method

1. Make Observation
2. Formulate hypothesis to explain observation
3. Test Hypothesis
   - Pass
   - Fail
4. Hypothesis → Theory
   - Pass
   - Fail
5. Theory → Law
   - Fail
• Pioneered studies in bee communication and foraging

• Demonstrated that honey bees use a dance language to communicate the location of food resources to other bees

• The waggle dance uses for communicate the position of a distance food source

• This dance communicates both the distance and direction using the sun, the hive, and the food source as reference points
Bee communication-
Karl von Frisch

- Trained European honey bees to feeders
- First believed bees used flower scents or other odors to find food sources
- Began to pay close attention to the dances performed by returning foragers
  - Dances very precise, with varying tempo and direction
von Frisch described the dances

“Round dance”

When food source is < 50 m from hive
“Wagggle dance”

When food source is >50 m away from hive
“Waggle dance”

Figure-8 portion resets position of dancer

Angle b/w vertical & waggle run = angle b/w sun & food source
von Frisch’s
Experimental evidence

DIRECTION
Train foragers to feeding station F.

Then, collect new recruits to all feeding stations (same distance).
DISTANCE

Train foragers to come to a feeding station 750 meters from the hive. Look at number of recruits to stations at various distances (same direction).
Honey bee waggle dance
Imprinting- Konrad Lorenz
Imprinting- Konrad Lorenz

- Learning that occurs during a sensitive or critical period in the early life of an individual
- Irreversible
- Include both learning & innate components, and generally irreversible
Konrad Lorenz & Geese hatchlings

- Behavioral observation: geese hatchlings closely follow their mother
- Explanation: Mother-offspring bonding in animals is crucial to safety & development of the offspring
- Hypothesis: Geese hatchlings follow the first thing they see that moves
Imprinting Lorenz’s testing

**Experiment:** A clutch of goose eggs was divided between the mother goose and an incubator (treated by Lorentz). Lorenz ensured that he was the first moving organism seen for the first time by the hatchlings.

**Results:** Goslings reared by the mother behaved normally and mated with other geese.
- Goslings that spent their first hours of life with Lorenz followed him wherever he went, preferred humans for the rest of their lives and even tried to mate with humans.

**Conclusions:** Greylags goose have no innate sense of "mother" or "gooseness". They identify with and respond to the first object with certain characteristics they encounter. The ability or tendency to respond is innate.
Imprinting for conservation

Conservation biologists have taken advantage of imprinting by young whooping cranes as a mean to teach the birds a migration route.

A pilot wearing a crane suit in an Ultralight plane acts as a surrogate parent.
Fixed Action Pattern (Instinct)  
Nikolas Tinbergen

- Highly stereotypic behavior
- Triggered by a **sign stimuli** (external stimulus)
- When stimuli are exchanged between members of the same species, the stimuli are called **releasers**
- Once begun, the behavior will continue to completion
- In some cases, aspects of the FAP need to be learned (trained) in order to master the behavioral repertoire
Tinbergen's Observations on the Bee Wolf

1. Observation - Female flies in a circle before going to hunt?

2. Hypothesis - Female is using landmarks to find the nest

3. Prediction - Female will return to a landmark to find the nest

4. Test - Place an artificial landmark around the nest and move it when the female is away

5. Result - Female orients to new landmark

6. Confirm hypothesis √
1. Question - Is the female responding to the cones or their scent

2. Hypothesis - Female is using visual cues to find the nest

3. Prediction - Female will return to a landmark to find the nest

4. Test - Place an artificial landmark around the nest and include scented (pine oil) pads

5. Move the cones and add unscented pads when the female is away but leave the scented pads at the nest

6. Result - Female orients to pine cones and not scented pads

7. Confirm hypothesis √
Tinbergen's Experiment: fixed action pattern in wasp nest finding behavior
Fixed Action Patterns:
Egg-rolling behavior of the greylag goose
• The goose will roll an egg that is outside the nest back into the nest in the same manner every time.

• The goose will do this with any round object placed outside the nest.

• Each time this action pattern is initiated, it is carried through to completion.
FAP social behavior in three-spined stickleback
(Key visual sign stimulus releasing)
Fixed action pattern in three-spined stickleback

- Will attack as long as red spot present on the ventral body part

- Will court if white swollen belly (i.e. a pregnant female)
2 Levels of Behavioral Studies

The study of *how* and *why* animals interact with each other (both within and among species) and their environment.

Proximate perspective

How is that...?  
What is that...?

Ultimate perspective

Why is it that...?

BEHAVIOR

Studying the mechanisms responsible for interactions (behavioral act)

How these interactions influence an individual's survival and reproduction
Proximate and ultimate perspectives on aggressive behavior by male sticklebacks

**BEHAVIOR:** A male stickleback fish attacks other male sticklebacks that invade its nesting territory

**PROXIMATE CAUSE:**
The red belly of the intruding male acts as a sign stimulus that releases aggression in a male stickleback

**ULTIMATE CAUSE:**
By chasing away other male sticklebacks, a male decreases the chance that eggs laid in his nesting territory will be fertilized by another male
Proximate and ultimate perspectives on imprinting in graylag geese

**Behavior:** Young geese follow and imprint on their mother

**Proximate Cause:**
During an early, critical developmental stage, the young geese observe their mother moving away from them and calling

**Ultimate Cause:**
On average, geese that follow and imprint on their mother receive more care and learn necessary skills, and thus have a greater chance of surviving than those that do not follow their mother.
Innate vs. Learned Behavior

- Behavior is modified by experience (trial and error pattern)
- Flexible. Phenotype is changing with time/experience
- Often affects even innately programmed behaviors, e.g., Fixed Action Patterns

![Diagram showing the process of behavior]
Learned behavior
A young chimpanzee learning to crack oil palm nuts by observing an experienced elder
Japanese macaques

One female started washing sand off of sweet potatoes

Others imitated her; they later taught their offspring to do so. She later learned to do this with grain

Her peers imitated her; the older males did not!
Instinct (innate) Behavior

- First time performance is completely functional
- Animals don't have to witness the behavior (inborn)
- Uniform, stereotyped
- Triggered by simple sign stimulus (sensory releaser)
- It has a strong genetic (inherited) basis: control by pre-programmed fixed neurological circuitries
Innate behavior
Nature: Instinctive/Innate Behavior

- Baby birds lifting their beaks for food
Innate behavior of the Cuckoo bird
Young cats learning to hunt.

Instinct to chase (nurture) combined with learning how to stalk and kill.
Innate behavior of the Egyptian vulture
More animal behavior videos?
Two ways to study animal behavior

It’s a rather interesting phenomenon. Every time I press this lever, that post-graduate student breathes a sigh of relief.
Experimental studies of animal behavior in laboratory conditions

Ivan Pavlov (1849-1936)

Burrhus Frederic Skinner (1904-1990)
Ivan Pavlov

The Nobel Prize in Physiology or Medicine 1904
For his research in temperament, conditioning and involuntary reflex actions of the digestive glands

Pavlov’s experiment:
The original and most famous example of classical conditioning involved the salivary conditioning reflex of Pavlov’s dogs.
Pavlov's Classical Conditioning

Before Training/Conditioning
Food → Salivation
Tone → ??? (nothing)

During Training/Conditioning
Tone → Food → Salivation

After Training/Conditioning
Tone → Food → Salivation
Definitions:

**Unconditioned Stimulus (UCS):** A stimulus that automatically elicits a response without any prior conditioning/learning.

**Unconditioned Response (UCR):** That unlearned reaction/response to an UCS without previous conditioning.

**Conditioned Stimulus (CS):** Is a previously neutral stimulus that, through pairing with the UCS, also eventually elicits a response.

**Conditioned Response (CR):** That reaction/response that occurs to the CS.
Pavlov’s Classical Conditioning
Example: Negative Classical Conditioning

Jonathan et al 2011; Cell
Video
Skinner's Operant Conditioning learning

“Everything we do and are is determined by our history of rewards and punishments.”-BF Skinner

• A process where an animal learns to associate one of its behaviors with a reward or punishment and then tends to repeat or avoid that behavior.

• In different to classical conditioning the response is voluntary (it is NOT a reflex) and the animal must do something to gain a reward (or avoid punishment)
Operant Conditioning: The Skinner Box
If your behavior is followed by a positive consequence, you are more likely to repeat the act in the future; if it is followed by a negative consequence, you are less likely to repeat it.
Example: Positive Operant Conditioning

Positive Reward: